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Cold Storage Influences the Postharvest Pericarp Browning and Quality of Litchi

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ABSTRACT

Occurrence of postharvest pericarp browning and rapid decay limit the postharvest storage life of litchi fruit. Effect of low temperature storage on the physico-chemical characteristics of two commercial litchi cultivars 'Bedana' and 'Serai' stored at 5°C for 0, 7, 14, 21 and 28 days were investigated. Incidence of pericarp browning, disease severity and fruit physico-chemical characteristics were determined immediately after each removal. During cold storage fruit firmness (15–5.1 N), weight loss (7.06–1.92%), aril: stone ratio (15.3–11.7) and sensory values of fruit decreased, whereas fruit pericarp browning index (0.33–3.25), postharvest disease index (0.5–2.4) and fruit cracking (0.08–1.16%) increased. Fruit weight loss, pericarp browning and disease severity were higher in 'Serai' than 'Bedana' fruit. The fruit of cv. 'Bedana' showed better aril: stone ratio (23.07), firmness (2.1 N), pH (4.15), SSC (19.04%), TA (0.14%), total sugars (12.11%) and ascorbic acid (44.8 mg 100 g^{-1}) contents than 'Serai'. Fruit flavour, texture and aroma changed rapidly during cold storage in 'Serai' than 'Bedana'. The pH of fruit juice showed slightly increasing trend during the whole span of storage, while SSC (20.4–17.4%), TA (0.23–0.05%), ascorbic acid (55–32.8 mg 100g^{-1}), total sugars (13.5–10.5%) and phenolics (0.71–0.45 µg 100 g^{-1}) showed decreasing trend. Litchi cv. 'Bedana' exhibited higher total phenolic contents (0.71 µg 100 g^{-1}) than 'Serai' (0.55 µg 100 g^{-1}). The fruit of cv. 'Bedana' were found superior having less weight loss, pericarp browning index and disease severity index, with higher aril: stone ratio, flavour, texture, aroma, pH, SSC, TA, ascorbic acid, total sugars and phenolic contents. Results suggest that postharvest pericarp browning and fruit quality deterioration can be delayed by cold storage. © 2012 Friends Science Publishers

Key Words: Ascorbic acid; Fruit quality; Litchi; Low temperature; Phenolics; Storage period

INTRODUCTION

The fruit industry of Pakistan is dominated by major fruits such as citrus, mango, banana and date; however litchi is an emerging subtropical fruit crop in Pakistan. It is grown successfully in Punjab (Lahore, Sharaq Pur, Shaikhupura, Sialkot, Taxilla, Cheecha Watni, Multan, Rahim Yar Khan & Kala Bagh), Khayber Pakhton Khaw (Haripur, Hazara, & Khan Pur) and Sindh (Nawab Shah, Moro, Mir Pur Khas, Tando Allah Yar & Hyderabad) (Rajwana *et al*., 2010).

Litchi fruit is preferred for its characteristic sweet-acidic taste, excellent aroma, high nutritive value, succulent aril and bright red colour of its peel. Litchi is a rich source of vitamin C, contains fair amount of phosphorus, calcium, iron, vitamins A and B (Anonymous, 2011). Litchi is an attractive, non-climacteric, highly perishable and environmentally most sensitive tropical to subtropical fruit crop. The fruit has a rough indehiscent pericarp surrounding the succulent, edible aril and a seed in the centre. Skin colour varies somewhat between cultivars, from the light orange-pink to the deep dull-red and purple-red (Sivakumar *et al*., 2010). Due to cultivar differences litchi fruit may vary widely in texture, size and shape, but one characteristic, which remains constantly desirable is fresh red skin.

Pericarp of the fruit lose its bright red peel color, which turns brown within 24 to 28 h after harvest (Zheng & Tian, 2006). Pericarp browning reduces its commercial value and has been considered the main postharvest problem worldwide (Kumar *et al*., 2011). The incidence of postharvest pericarp browning in litchi fruit is regulated by various factors such as activity of polyphenol oxidase (PPO) enzyme (Zauberman *et al*., 1991), desiccation (Scott *et al*., 1982), changes in endogenous anthocyanins contents (Underhill & Critchley, 1994), storage conditions (Sivakumar & Korsten, 2006), storage temperature (Jiang *et al*., 2003b), postharvest fruit coatings (Joas *et al*., 2005), hot water treatments (Olesen *et al*., 2004), postharvest application of polymaines, antioxidants (Kumar *et al*., 2011), ascorbic acid (Sun *et al*., 2010), oxalic acid (Zheng & Tian, 2006) and cultivars (Sivakumar *et al*., 2010). However, among these factors, rapid moisture loss, degradation of anthocyanin by PPO and peroxidase

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enzymes and decrease in antioxidants levels are mainly responsible for pericarp browning in litchi (Sun *et al*., 2010). Various approaches have been used to overcome this problem, however, a complete solution is not available and the use of chemical needs strict control due to potential health risks (Wilson & Wisniewiski, 1989).

At present no information is available about the postharvest storage potential, level and intensity of pericarp browning for locally grown litchi cultivars in Pakistan. Keeping in view the emerging demand of this potential fruit both in local as well as international markets, there is great need to explore the postharvest storage potential of commercial litchi cultivars in Pakistan. This will further help to develop postharvest handling and management strategies with some innovative techniques to extend the postharvest storage life without compromising losses in its quality? Hence, the present research was carried out to study the response of cold storage on the incidence of pericarp browning and physico-chemcial fruit quality of two commercial litchi cvs. 'Bedana' and 'Serai'.

MATERIALS AND METHODS

Plant material: Two (widely cultivated in Pakistan) litchi cultivars 'Bedana' and 'Serai' were harvested at commercial maturity from the Fruit Nursery Farm Haripur (33°59'N; 72°56'E), Khayber Pakhton Khaw during 2009. After harvest fruits of each cultivar were transported to Postharvest Research and Training Centre, Institute of Horticultural Sciences, University of Agriculture Faisalabad. Fruits uniform in size, shape, colour, lack of physical damage and injury caused by insects and diseases were selected for the experiment. Fruits of both cv. were stored at 5±1°C and 80–85% RH for 0, 7, 14, 21 or 28 days. Ten fruit were taken as treatment unit replicated three times. Fruit physical (pericarp browning index, postharvest disease index, fruit cracking percentage, fruit firmness, aril: stone ratio, weight loss & organoleptic characteristics) and biochemical [(pH, soluble solids concentration (SSC), titratable acidity (TA), ascorbic acid, total sugars (TS) and total phenolics)] characteristics were determined immediately after each removal.

Physical fruit quality characteristics: Pericarp browning and postharvest disease index was assessed by using the scale (Jiang & Chen, 1995) (Table I). Fruit with cracked peel were separated from non-cracked by physical observation and were expressed as percentage. The fruits were also evaluated for organoleptic characteristics including appearance, colour, texture, taste and flavour using arbitrary scale ranging from 1–9 (Peryam & Pilgrim, 1957). A panel of ten judges was asked to perform sensory assessment using the Hedonic scales. Fruit firmness was determined with the help of Penetrometer by removing peel from 5 mm area and inserting the probe and was expressed as N. Aril: stone ratio was calculated in each sample by dividing the percentage of aril with the percentage of the stone. Weight loss was calculated by using formula:

Table I: Scales used for postharvest pericarp browning and disease severity

Pericarp browning index	Disease severity index
1 = no browning (excellent quality)	1 = no fruit infected
2 = slight browning	2 = > 0 - 5 % infected fruits
3 = < ¼ browning	3 = > 5 - 10 %infected fruits
4 = ¼ to ½ browning	4 = > 10 - 25 % infected fruits
5 = > ½ to ¾ browning (poor quality)	5 = > 25 - 50% of infected fruits
6 = >3/4 browning (very poor quality)	6 = > 50 % of infected fruits

$$X = [(Y-Z)/Y]\ 100$$

Where X = % weight loss, Y = weight before storage, Z = weight after storage.

SSC, TA and SSC: TA ratio: SSC of fruit juice was determined by hand held refractometer (ATAGO, RS-5000 Atago, Japan). The pH was determined by using digital pH meter (HI 98107, Hanna Instruments, Mauritius). The method outlined by Khan *et al*. (2011) was used to determine the TA of juice. In which 10 mL of juice taken in 100 mL conical flask was diluted up to 50 mL with distilled water. It was titrated against 0.1 N NaOH, using 2–3 drops of phenolphthalein as an indicator till pink colour end point was achieved and TA was expressed as percentage (%). SSC: TA ratio was calculated by dividing SSC with TA value.

Ascorbic acid and sugars: Ascorbic acid contents of fruit juice were determined by the method described by Ruck (1969). Ten mL of juice was diluted with 0.4% oxalic acid solution in 100 mL volumetric flask. Five mL of diluted and filtrated aliquot was titrated against 2, 6–dichlorophenolindophenol dye, to light pink colour end point. Sugars in juice were estimated following the method of Hortwitz (1960). Ten mL juice taken in 250 mL volumetric flask was diluted with 100 mL water, 25 mL 25% lead acetate solution and 10 mL 20% potassium oxalate. Then the volume was made with distilled water. The filtrate was used for the estimation of different forms of sugars. Sugars were expressed as percentage.

Total phenolics: Total phenolics were determined by the method described by Ainsworth and Gillespie (2007). One gram of sample was taken and homogenous mixture was made with 20 mL methanol. The mixture was then poured into the Falcon tubes and shaked for 2–3 min and filtered into the patri dishes. After evaporation the supernatant were screened by adding 1 mL distilled water. Then 100 µL of supernatant was mixed with 200 µl of Folin-Ciocalteu reagent and 800 µL of Na_2CO_3 before taking the absorbance of 200 µL of this mixed sample using 96-well microplate at 765 nm using spectrophotometer (Gen Elisa machine, Micro Quant, Bio Tek, USA). Standard curve was made from the blank-corrected A_{765} of the gallic acid standards and total phenolics were calculated as gallic acid equivalents using the regression equation between the gallic acid standards and A_{765}.

Statistical analysis: The data were analyzed statistically by Genstat (release 31.1; Lawes Agricultural Trust, Rothamsted Experimental Station, Rothamsted, UK) and mean separation was done by least significant difference (LSD) following significant ($P \leq 0.05$) F test. All assumptions of the analysis were checked to ensure the validity of statistical analysis.

RESULTS AND DISCUSSION

As expected both cultivars exhibited gradual decrease in fruit firmness as storage period progressed (Fig. 1A). Up to 14 days of cold storage fruit of cv. 'Serai' were 1.4-fold firm than 'Bedana'. Later on both cultivars did not exhibit any differences in their fruit firmness. During cold storage, fruit of cv. 'Serai' exhibited 1.3-fold higher fruit weight loss then 'Bedana' (Fig. 1B). Mean fruit weight loss in 'Bedana' was 1.4-fold less than 'Serai' during cold sotrage. Fruit of cv. 'Bedana' showed 6.4-fold higher mean aril:stone ratio than 'Serai'. Aril: stone ratio of Bedana' fruit decreased significantly ($P \leq 0.05$) with increase in the cold storage period, whereas during cold storage fruit of cv. 'Serai' did not exhibit any significant change in their aril: stone ratio (Fig. 1C). This reduction in fruit firmness may be attributed to the advancement in fruit ripening process which continued during low temperature storage even at 5°C. A similar reduction in fruit firmness has been reported earlier by Shah and Nath (2008) in litchi fruit during storage and the extent of loss of fruit firmness was depended upon the method of storage. It was found that fruit weight was lost during the whole span of storage right from the first day of storage to the end of the storage but slowly than normal temperature. Olesen and Wiltshire (2000) also found that high humidity and low temperature reduce weight loss in litchi during storage. Litchi cv. 'Bedana' had small stone than 'Serai' so exhibited better aril: stone ratio as compared to 'Serai'. The pulp, which is the edible portion of fruit is more in 'Bedana' than 'Serai', which increased the preference of 'Bedana' over 'Serai'. During cold storage, fruit weight loss was increased gradually as the storage period progressed (Fig. 1B). Mean fruit weight loss was 4.94% higher in litchi cv. 'Serai' than 'Bedana' (Fig 1B).

Incidence of pericarp browning increased with increase in the cold storage period in both cultivars (Fig. 2A). Mean incidence of pericarp browning was 14.29% higher in the 'Bedana' than 'Serai' fruit. During cold storage period, disease severity index also increased as the cold storage period progressed. Throughout the cold storage period fruit of cv. 'Serai' showed higher disease severity index than 'Bedana'. Mean disease severity index in 'Serai' fruit were 23.53% higher than 'Bedana (Fig. 2B). Similar to disease severity index the occurrence of fruit cracking in 'Serai' fruit increased with advancement in storage period (Fig. 1C). During first two weeks of storage, fruit of cv. 'Bedana' did not exhibit any fruit cracking later on it increased as the storage period progressed; however, it

Fig. 1: Effect of cold storage on fruit firmness (A), fruit weight loss (B), and aril: stone ratio (C) of litchi cvs. 'Bedana' and 'Serai' fruit. Vertical bars indicate ± SE of means. n = 3 replicates

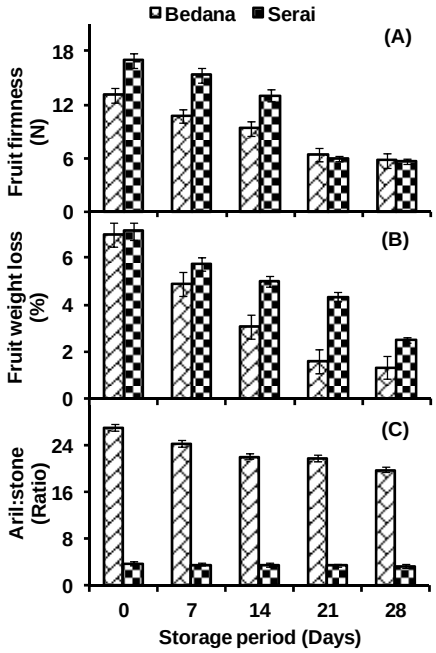


Fig. 2: Effect of cold storage on pericarp browning index (A), diseased severity index (B), and fruit cracking index (C) of litchi cvs. 'Bedana' and 'Serai' fruit. Vertical bars indicate ± SE of means. n = 3 replicate

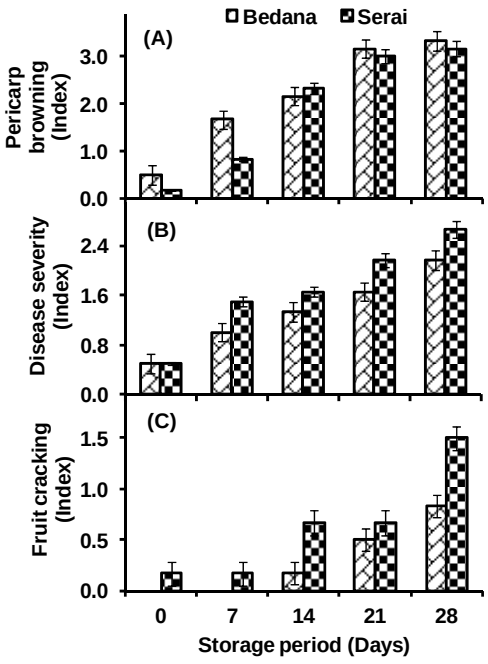
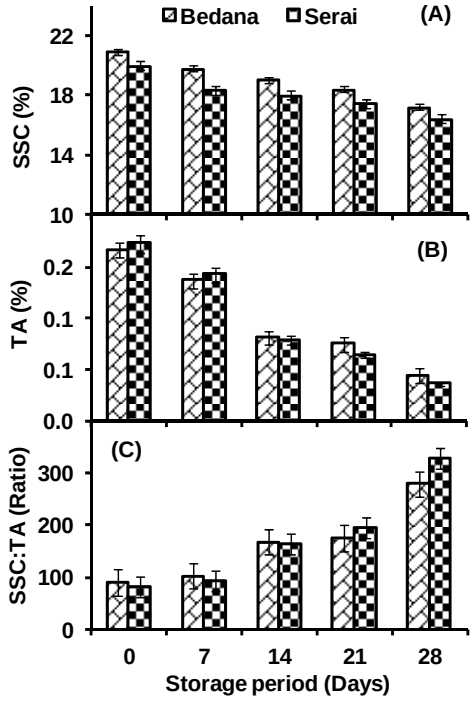


Table II: Effect of cold storage on the physical quality of litchi fruit

Storage period (Days)	Aroma		Flavour		Colour		Texture		Taste	
	Bedana	Serai	Bedana	Serai	Bedana	Serai	Bedana	Serai	Bedana	Serai
0	8.5a	8.11a	8.5a	8.01a	8.73a	8.23a	8.48a	7.91a	8.6a	8.26a
7	8.10b	7.78b	8.01b	7.9b	7.90b	7.70b	8.13b	7.7a	8.4a	8.10b
14	7.9bc	7.58c	7.83c	7.73c	7.60c	7.60b	7.93b	7.4b	8.2b	7.95b
21	7.75cd	7.35cd	7.66d	7.55d	7.50d	7.20c	7.81c	7.4b	7.95c	7.53c
28	7.50d	7.16d	7.4e	7.45e	7.20e	7.10c	7.71c	7.4b	7.78c	7.21c
Mean	7.95	7.6	7.88	7.73	7.79	7.57	8.01	7.4	8.19	7.81
($P \leq 0.05$)	0.20	0.20	0.21	0.21	0.14	0.14	0.19	0.19	0.17	0.17

Any two means within a column followed by the same letter are not significant at ($P \leq 0.05$)

Fig. 3: Effect of cold storage on SSC (A), TA (B) and SSC:TA ratio (C) of litchi cvs. 'Bedana' and 'Serai' fruit. Vertical bars indicate ± SE of means. n = 3 replicates.



remained lower than 'Serai'. After 28 days of cold storage 'Serai' fruit exhibited highest about 46.78% higher fruit cracking than 'Bedana'. Browning occurs due to the dehydration of pericarp tissues with excessive loss of water. Cell breakdown during harvesting, grading and packing may also enhance browning. In the present study the higher rate of pericarp browning index in 'Bedana' might be due to varietal character as these fruit exhibited lower fruit loss with higher fruit firmness than 'Serai'. Our findings supported by the results of Jiang and Fu (1998) who reported that litchi pericarp is highly susceptible to desiccation and skin browning increased with storage time. The increase in the pericarp browning was coincided with storage period. During storage disease severity index increases but slowly than ambient temperature. Litchi cv. 'Serai' showed more disease severity index than 'Bedana'. Earlier it has been reported that litchi fruit stored at 5°C maintained better quality and had less disease severity index than fruit stored at higher temperatures for two to three weeks (Jiang *et al*., 2003b). Cold storage has been reported to delay or slow down the decay and senescence process in stored litchi fruit than control (Johnson *et al*., 2002; Sivakumar *et al*., 2010). During storage the fruit cracking percentage was remained constant (0.08) from the day of harvest to the 14th day of storage and increased from 14th day of storage to last day. This showed that lowering the temperature at the time of storage was effective in reducing or eliminating fruit cracking, which is an important attribute of quality. Ramma (2003) also observed decline in fruit cracking % at low temperature than ambient temperature.

Aroma of litchi fruit decreased significantly ($P \leq 0.05$) during cold storage. At the time of harvest aroma of fruit was extremely like and after 28 days of cold storage fruit become moderately unlike (Table II). The aroma of litchi cultivar 'Serai' was less intense than the 'Bedana'. Maximum scale rating (8.5) for flavour was recorded just after harvest and minimum (7.4) at the 28th day of storage. Flavour scores were very high initially which significantly decreased as the cold storage period progressed (Table II). Litchi cultivar 'Bedana' exhibited better flavour than 'Serai'. This reduction in the flavour scores of litchi during the storage might be due to loss of sugars and TA as reported by Shah and Nath (2008). Pulp colour was recorded maximum (8.73 & 8.23) after harvest at 0 day of storage and lowest (7.2 & 7.1) after 28 days of cold storage (Table II). Colour scores were extremely like initially, which significantly decreased during storage. Litchi cv. 'Bedana' exhibited higher (7.79) mean pulp colour than 'Serai' (7.57) (Table II). Result showed that pulp colour showed a general tendency to decrease with storage period. The loss of colour scores was due to the development of browning on the pericarp of fruit (Fig. 2A). Texture score was decreased as the storage span increased for both litchi cvs. up to 28 days of storage (Table II). The decrease may be attributed to the loss of water from fruit during storage, which gave a shrunken appearance to fruit and hence reduced the texture of the stored fruit (Shah & Nath, 2008). Initial taste scores of litchi fruit were found to be 8.6 and 8.26, which decreased (7.78 & 7.21) significantly after 28

Fig. 4: Effect of cold storage on reducing sugar (A), non-reducing sugar (B), and total sugar (C) contents of litchi cvs. 'Bedana' and 'Serai' fruit. Vertical bars indicate ± SE of means. n = 3 replicates

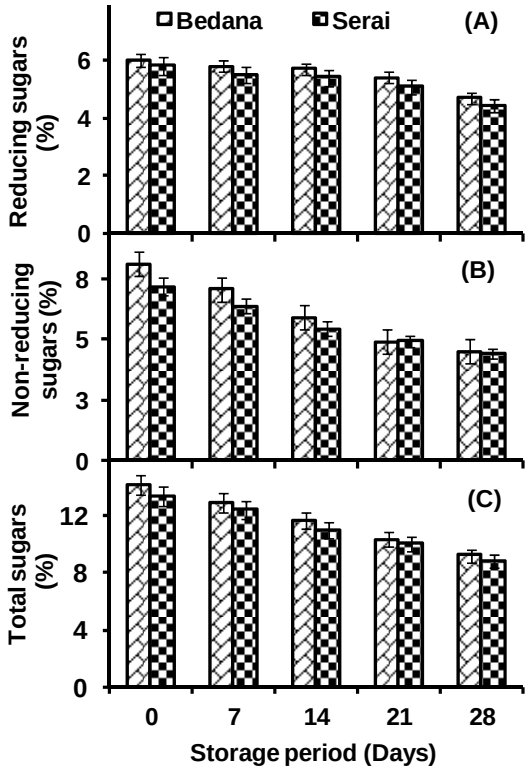
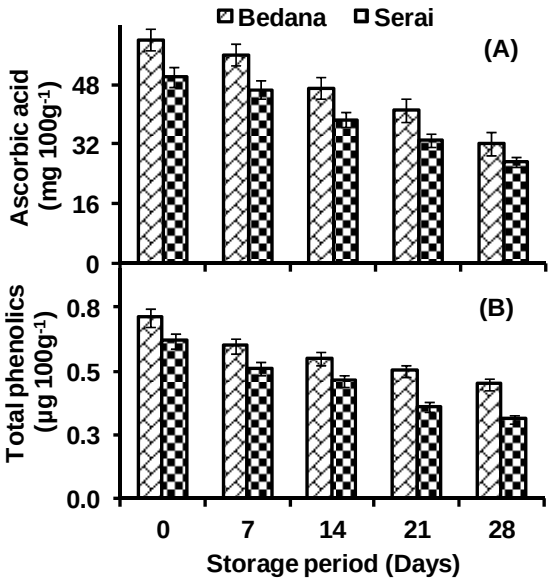


Fig. 5: Effect of cold storage on level of ascorbic acid (A), and total phnolics (B) contents of litchi cvs. 'Bedana' and 'Serai' fruit. Vertical bars indicate ± SE of means. n = 3 replicates



days of cold storage for 'Bedana' and 'Serai' respectively (Table II). Taste scale of litchi pulp decreased rapidly during storage. The taste scale is one of the important quality attribute of litchi fruit and moreover, the decrease in the taste scale was associated well with the reduction in the colour scale (Jiang *et al*., 2003a).

The SSC of litchi fruit juice decreased significantly ($P \leq 0.05$) with increase in storage period at 5°C (Fig. 3A). Maximum SSC was recorded at 0 days of storage i.e. at harvest (20.42%), while minimum (17.35%) was after 28 days of storage. "Bedana' fruit exhibited higher mean SSC than 'Serai' throughout the storage period. In this experiment TA of the fruit showed a general tendency to decline significantly ($P \leq 0.05$) as the storage period progressed (Fig. 3B). Similar to SSC, the mean TA of the 'Bedana' fruit remained higher than 'Serai' during the cold storage. SSC: TA ratio of the litchi fruit increased with increase in the period of cold storage. Minimum SSC: TA ratios for 'Bedana' (89.56) and 'Serai' (82.59) were recorded at 0 day of storage and maximum (279) and (328) after 28 days of storage, respectively (Fig. 3C). During cold storage, the differential rate of decrease in SSC leads to an increase in the sugar to acid ratio. This imbalance in the sugar: acid ratio is confirmed by a reduction in the eating quality as the fruits developed an insipid taste, with an increase in storage period (Table II). Chemical analysis of samples of litchi fruit aril before and just after analysis showed significant change in TA content. Similarly, Zauberman *et al.* (1991) also reported a significant decrease in TA with increase in period of cold storage without any remarkable effect on the eating quality of litchi fruit.

Reducing, non-reducing and total sugars of fruit juice of both litchi cultivars decreased gradually with increase in storage period (Fig. 4). However, fruit of cv. "Bedana' exhibited higher amount of reducing, non-reducing and total sugars than 'Serai'. Reduction in the sugar during storage may be ascribed to the advancement of fruit ripening with accelerated rate of respiration. Similarly, in earlier studies reduction in the sugar contents have also been found during storage in 'Hei Ye' and 'Chen Zi' litchi fruits (Paull & Chen, 1987).

Level of ascorbic acid in both litchi cultivars decline as the period of cold storage increased (Fig. 5A). However, ascorbic acid contents in the 'Bedana' fruit remained higher than 'Serai' throughout the ripening period. After 28 days of cold storage 'Bedana' and 'Serai' fruit exhibited 1.9-fold and 1.8-fold reduction in their ascorbic acid contents than before storage respectively. Mean ascorbic acid contents in 'Bedana' (15.4%) were higher than 'Serai'. The loss of ascorbic acid during storage may be ascribed to its higher oxidation rate, which consequently increased its degradation and browning (Gimnez *et al.,* 2003). A similar pattern of reduction in the level of ascorbic acid during storage has been observed in fresh cut apple stored at 4°C (Soliva-Fortuny *et al*., 2004). Like ascorbic acid contents, the level of total phenolics in the both litchi cultivars

decreased during cold storage. 'Bedana' fruit exhibited higher total phenolics throughout the cold storage than 'Serai' (Fig. 5B). 'Serai' fruit exhibited 16.1% lower total phenolics than 'Bedana'. Total phenolic contents decreased during the whole storage period and maximum (0.71 µg 100 g^{-1}) value was recorded at 0 day of storage and minimum (0.45 µg 100 g^{-1}) at 28th day of storage. Litchi cv. 'Bedana' (0.70 µg 100 g^{-1}) exhibited more phenolics then 'Serai' (0.50 µg 100 g^{-1}). Reduction in the total phenolic contents during cold storage showed that low temperature may delay the process of degradation but cannot completely stop it. Low temperature during storage may induce the oxidative stress that results in the degradation of phenols under stress conditions, however at slower rates. Presence of these phenolic contents in litchi exhibit excellent antioxidant activity and they are effective in scavenging superoxide anion radicals and inhibiting deoxyribose degradation. In addition, these phenolics significantly delayed the increase in electrolyte leakage and consequenlty prevent pericarp browning of the fruit.

In conclusion fruit of cv. 'Bedana' were found superior having less weight loss, pericarp browning index and disease severity index, with higher aril: stone ratio, flavour, texture and aroma, pH, SSC, TA, ascorbic acid, total sugars and phenolic contents during cold storage. Results suggest that postharvest pericarp browning and fruit quality deterioration can be effectively delayed by cold storage.

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